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6 OCT 1976

PTPS REPORT NO. 76-17
AFPEA PROJECT NO. 74-P7-16

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1473 in file

TEST AND EVALUATION RESULTS OF THE MONSANTO PLASTIC SHIPPING AND PACKAGING CONTAINER SYSTEM

Attn: AFALD/PTP
AIR FORCE PACKAGING EVALUATION AGENCY
Wright-Patterson AFB OH 45433

July 1976

NOTICE

ABSTRACT

Prototype containers, developed and furnished by Monsanto Research Corporation under Contract F33601-72-C-0424, were evaluated according to Federal Test Method 101B, Method 5005 (Cornerwise Drop Test), Method 5008 (Edgewise Drop Test) and Method 5012 (Pendulum Impact Test). The containers met these requirements. The AIM-7 containers cushioned with MIL-P-26514 polyurethane foam provided shock attenuation of not more than 24 G's. (The maximum allowable was 30 G's.) The Monsanto manufacturing method, while cheaper and simpler than conventional container manufacturing methods, still requires specialized equipment. Further development is recommended into other promising methods and materials such as the polyurethane foam methods and technology.

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TABLE OF CONTENTS

Page

PURPOSE

The purpose of this report is to document the test and evaluation results of the containers delivered to AFPEA under Contract No. F33601-72-C-0424, and to determine if the container manufacturing process is feasible for manufacturing containers for the Air Force.

BACKGROUND

Contract No. F33601-72-C-0424 was awarded to Monsanto Research Corporation, Dayton, Ohio to develop new low cost effective plastic materials and process systems for manufacturing shipping and packaging containers for military items. The development program was divided into three tasks.

Task I covered the formulation, development, production, evaluation, analysis, and selection of plastic materials that can be manufactured in a cost effective manner into containers and crates.

Task II required the manufacture of selected container panels, evaluation of their mechanical, thermal, and environmental properties, and refinement of the design and manufacturing process for the final containers and crates.

Task III required the manufacturing of 12 CNU-100 bombing dispensing containers and 12 AIM-7 material containers and submission to AFPEA for testing and evaluation.

The contract was completed by providing the Air Force with the delivery of 12 CNU-100 Bomb Dispenser containers and 12 AIM-7 Missile Propulsion Section containers of two designs. The contract work is documented under Monsanto Report No. MRC-DA-420. (NOTE: The CNU Bomb Dispenser container design was a modification of the current production design to allow for the use of the froth epoxy foam manufacturing system as shown in Figure 5.)

The container manufacturing concept is based on the use of a shaving cream-like froth which can be poured into a cavity and cured to a rigid foam at room temperature. The foam material is an epoxy which has excellent adhesion and energy absorbing characteristics. The cavity is formed by the void space between a simple mold (box, bag, etc.) and the part to be packaged. The foam then provides a container which is intimately conformal with the item to be packaged. The froth is made in a machine which requires only filling with liquids. A skin of polyester/chopped-fiberglass was applied to the exterior of the foam block to assist in rigidizing, providing better load and impact energy distribution, and to provide a degree of resistance from moisture, heat, and sharp projections. The prototype foam containers are shown in Figures 1, 2 and 5.

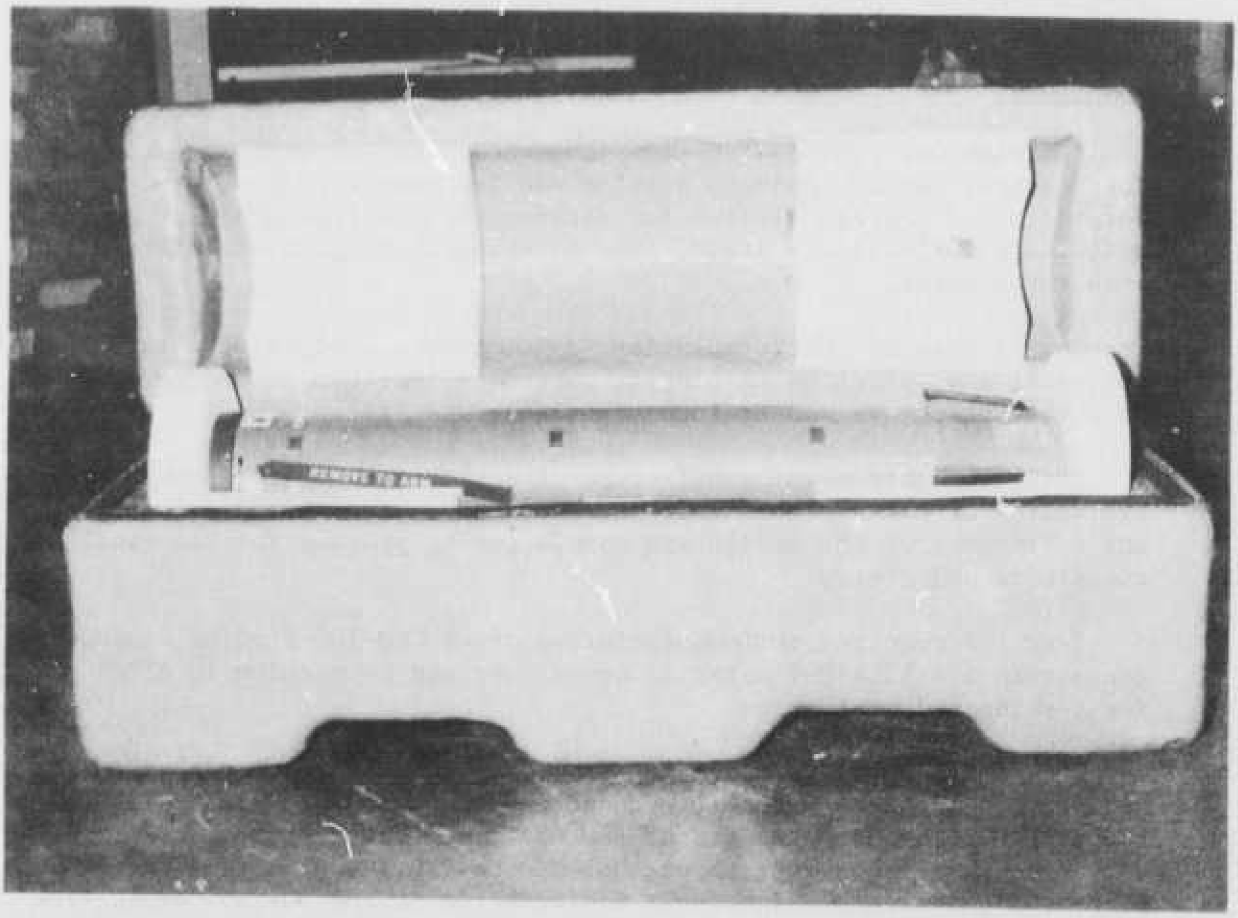

Figure 1. AIM-7 Container Showing Placement of Foam Cushioning Pads

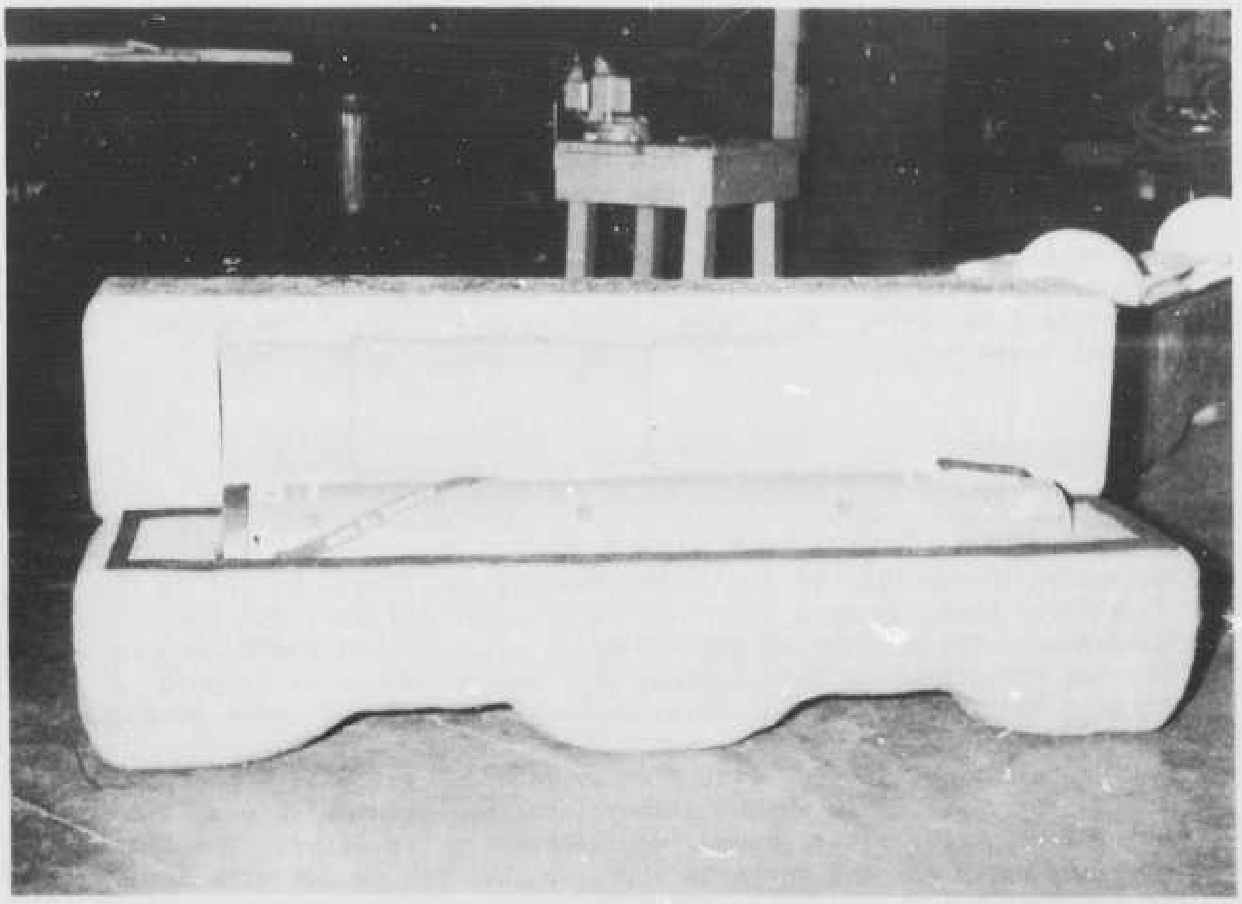

Figure 2. AIM-7 Container - The Item Was Used As Part Of The Mold

TEST AND EVALUATION PROGRAM

Table I is a listing of the containers delivered by Monsanto Research Corporation on Contract No. F33601-72-C-0424. The table gives the densities of the foam, weight of the foam, weight of the skins of fiberglass/polyester, and total weights of the containers. Containers were selected from this table with the higher density foams and skin weights so that the containers with superior properties could be tested first. If these selected containers did not meet the requirements, the containers with lesser physical properties would not be evaluated. The containers were delivered to AFPEA 1 Apr 1974. They were stored until the approximate date of the tests.

TEST PROCEDURE

EDGEWISE AND CORNER TESTING OF CONTAINER NO. 169140. To determine the ability of the large shipping containers to resist the impacts of being dropped edgewise and on their corners, and for determining the ability of the container with optimum cushioning to provide protection to the contents when the container is dropped, Federal Test Method Std No. 101B, Methods 5005 and 5008 were conducted.

Container No. 169140, with a epoxy foam density of 3.6 pounds per cubic foot (pcf), skin weight (fiberglass/polyester) 55.2 pounds and a total weight of 117.7 pounds, was selected for testing. The AIM-7 missile, which was the packaged item, weighed 169 pounds with diameter of eight inches.

The container was cushioned with 2 pcf polyethylene foam, with dimensions of 3" thickness and 12" wide and extending around the inside at the hard points on each end. Figure 1 is a photograph of the package unit showing the placement of the foam pads. The containers were closed with plastic strapping as shown in Figure 3.

Three accelerometers were attached to the test items to monitor the drop data. The acceleration developed from the drops was displayed on a storage oscilloscope. (Instrumentation used is listed in Table II.) Figure 4 shows AIM-7 container in dropped condition.

TABLE I

WEIGHTS OF THE MANUFACTURED CONTAINERS (EPOXY FOAM BLOCKS AND GLASS/POLYESTER SKINS)

Sample No.[a]	Container Design	Foam Density lbs/cu ft	Total Foam Wt lbs	Skin Wt lbs	Total Container Wt lbs
169150 169149	CNU-100	6.0	71.4	0.0	71.4
169129 169128	CNU-100	4.1	48.4	35.0	83.4
169131 169130	CNU-100	3.4	39.9	26.9	66.8
169127 169124	CNU-100	3.3	38.8	31.8	70.6
169136 169135	CNU-100	4.2	49.9	35.7	85.6
169133 169132	CNU-100	4.6	53.8	41.8	95.6
169138 169137	CNU-100	3.5	41.7	43.8	84.8
169144 169142	CNU-100	3.9	45.9	39.4	85.3
169140 169139	CNU-100	3.9	46.0	41.8	87.8
169148 169147	CNU-100	5.9	69.7	34.7	104.4

TABLE I (CONTINUED)

WEIGHTS OF THE MANUFACTURED CONTAINERS (EPOXY FOAM BLOCKS AND GLASS/POLYESTER SKINS)

Sample No.[a]	Container Design	Foam Density lbs/cu ft	Total Foam Wt lbs	Skin Wt lbs	Total Container Wt lbs
169146 169145	CNU-100	9.2	107.9	38.7	146.6
169152 169151	CNU-100	6.6	77.6	59.3	136.9
169150 169149	AIM-7 small	5.6	57.4	0.0	57.4
169132 169131	AIM-7 small	3.4	34.7	26.1	60.8
169135[b] 169133	AIM-7 small	3.6	36.5	38.3	74.8
169152 169151	AIM-7 small	5.9	60.4	33.2	93.6
169153T 169153B	AIM-7 large	3.6	60.0	0.0	60.0
169137 169136	AIM-7 large	4.2	73.1	43.1	116.2
169140 169138	AIM-7 large	3.6	62.5	55.2	117.7

TABLE I (CONTINUED)

WEIGHTS OF THE MANUFACTURED CONTAINERS (EPOXY FOAM BLOCKS AND GLASS/POLYESTER SKINS)

Sample No.[(a)]	Container Design	Foam Density lbs/cu ft	Total Foam Wt lbs	Skin Wt lbs	Total Container Wt lbs
169144 169142	AIM-7 large	4.2	70.6	50.9	121.5
169148 169147	AIM-7 large	4.2	71.5	45.4	116.9
169146 169145	AIM-7 large	5.0	85.2	47.2	132.4
169154 T 169154 B	AIM-7 large	3.4	57.2	50.4	107.6
169155 T 169155 B	AIM-7 large	3.7	62.7	53.4	116.1

(a) Sample numbers are arranged together with the first number being the top part of the container.
(b) This container has 4 handles attached to the bottom part.

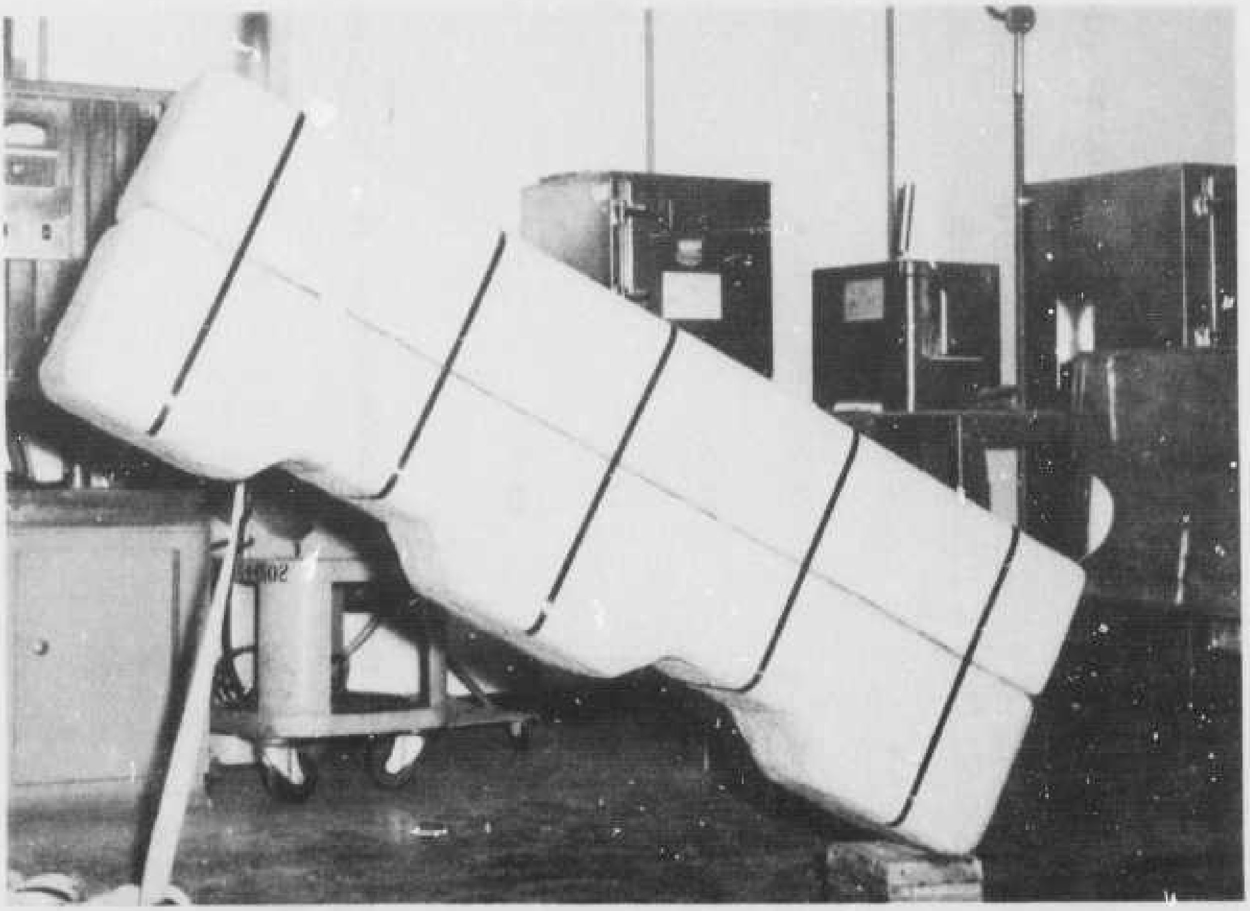

Figure 3. AIM-7 Container In Lifted Position For Drop Test - Note Banding of Container

TABLE II

INSTRUMENTATION FOR TESTING ITEM

Accelerometers, Piezoelectric, Three-Mounted in Triaxial Configuration
ENDEVCO Model 2233E

Amplifiers, Charge Type, - Three
ENDEVCO Model 2614

Oscilloscope, Storage Type
TECKTRONIX Model 564

Power Supply, D.C.
ENDEVCO Model 2622

Figure 4. AIM-7 Container in the Dropped Condition

The data developed from the instrumented drop tests is displayed in Table III below:

TABLE III

INSTRUMENTED DROP TEST
36" DROP HEIGHT

Type of Test	Cushioning Material	Vert Comp	Logitudinal Component	Lateral Comp	Resultant
		G's	G's	G's	G's
Edgewise	Polyethylene	40	26	43	$\sqrt{4125} = 64.2$
Edgewise	Polyethylene	56	40	30	$\sqrt{5636} = 75$
Cornerwise	Polyethylene	8	18	8	$\sqrt{452} = 21.2$
Cornerwise	Polyethylene	42	6	6	$\sqrt{1836} = 42.8$
Cornerwise	Polyethylene	42	5	9	$\sqrt{1870} = 43.2$
Cornerwise	Polyethylene	22	7	12	$\sqrt{677} = 26$
Edgewise	Polyurethane	16	12	8	$\sqrt{464} = 21.5$
Edgewise	Polyurethane	18	12	8	$\sqrt{532} = 23$
Cornerwise	Polyurethane	10	7	8	$\sqrt{213} = 14.5$
Cornerwise	Polyurethane	18	7	13	$\sqrt{542} = 23.3$
Cornerwise	Polyurethane	15	10	11	$\sqrt{446} = 21$
Cornerwise	Polyurethane	10	17	10	$\sqrt{489} = 22$

The maximum G's allowable for AIM-7 missile is 30 G's. The three inch polyethylene cushioning gave results that were above 30 G's and was not an acceptable cushioning. The three inch polyurethane cushioning gave results below 24 G's and this cushioning is satisfactory for protection of the item.

The corners of the container were crushed, but not sufficiently to be considered a failure. It was decided that all containers should be reinforced with two layers of fiberglass/polyester resin.

PENDULUM IMPACT TEST

To determine the ability of the containers to resist horizontal impacts, and to determine the ability of the restraining devices to protect the contents when the container is impacted, Federal Test Method Std No. 101B, Method 5012 was conducted.

Figure 1 shows the 2 pcf polyethylene foam pads (2" thick, 10" diameter) in place at the ends of the missile. Each end was subjected to an impact velocity of seven feet per second. The container and its contents were not damaged.

NON-INSTRUMENTED DROP TESTS

The evaluation program was continued on several containers without monitoring the shock loads with electronic instrumentation. The AIM-7 containers and item were packaged using polyurethane foams pads as described in the instrumented test. The CNU-100 container was designed using a simulated item as a mold. Figure 5 is a photograph of the item in the container. Figure 6 is a photograph of the closed container. Plastic strapping was used to close the container.

Table IV gives a summary of the characteristics of the containers and the results of the tests at room temperature and -40°F. All containers passed the edgewise and corner drop tests.

Figures 7 and 8 show cross-sections of the container. The bottom corners were damaged by the drop test. The degree of damage was not considered sufficient to designate the test results as a failure.

DEFICIENCIES OBSERVED ON THE CONTAINERS

The chopped fiberglass fragment ends protruded through the skin coating causing handling of the containers to be hazardous to personnel since unprotected hands could be easily cut or scratched. The protruding fiberglass ends should be eliminated. The corners of the container should be reinforced with either a stronger foam or fiberglass cloth/polyester resin to prevent any damage from crushing. The forklift entries should be positioned so as to match the forklift tines location.

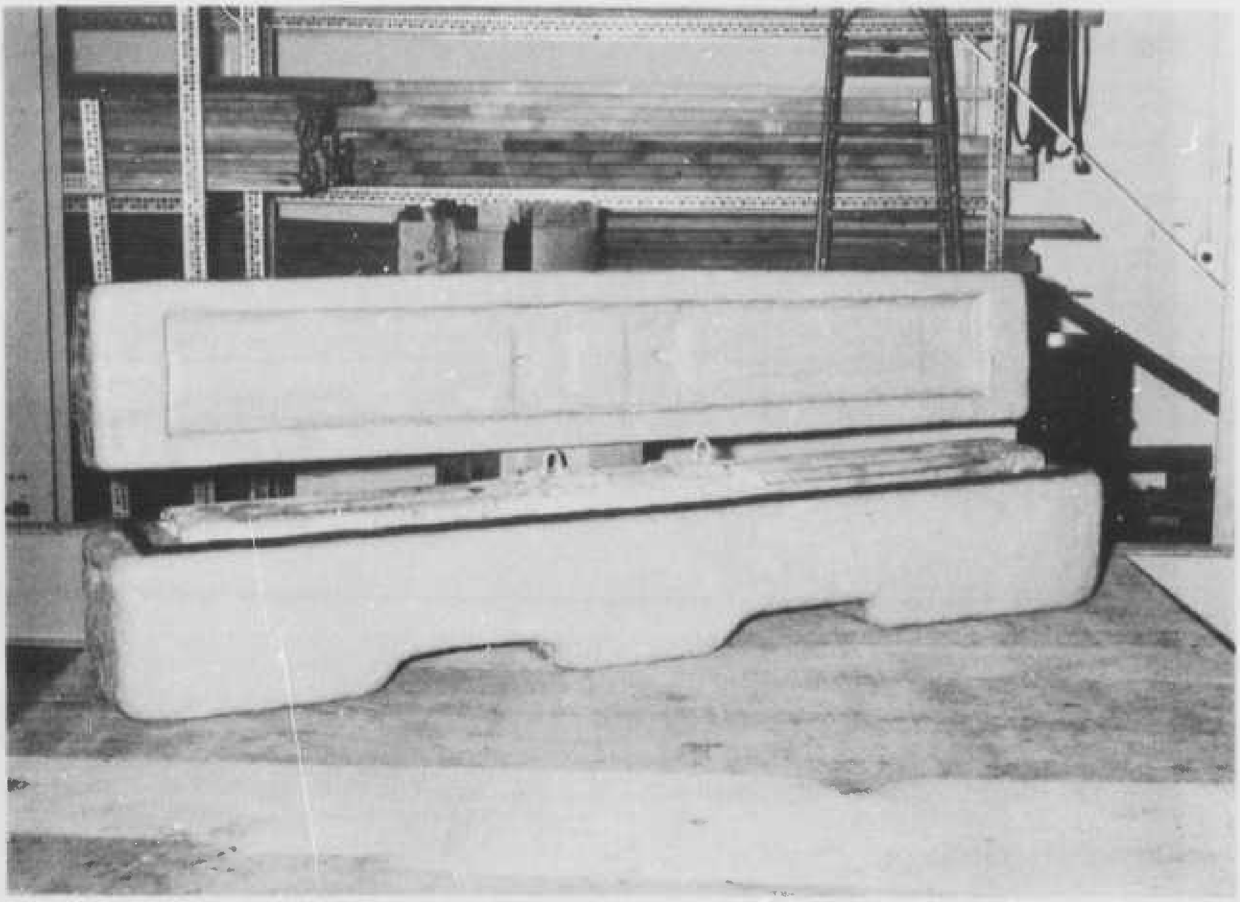

Figure 5. CNU-100 Missile in Container

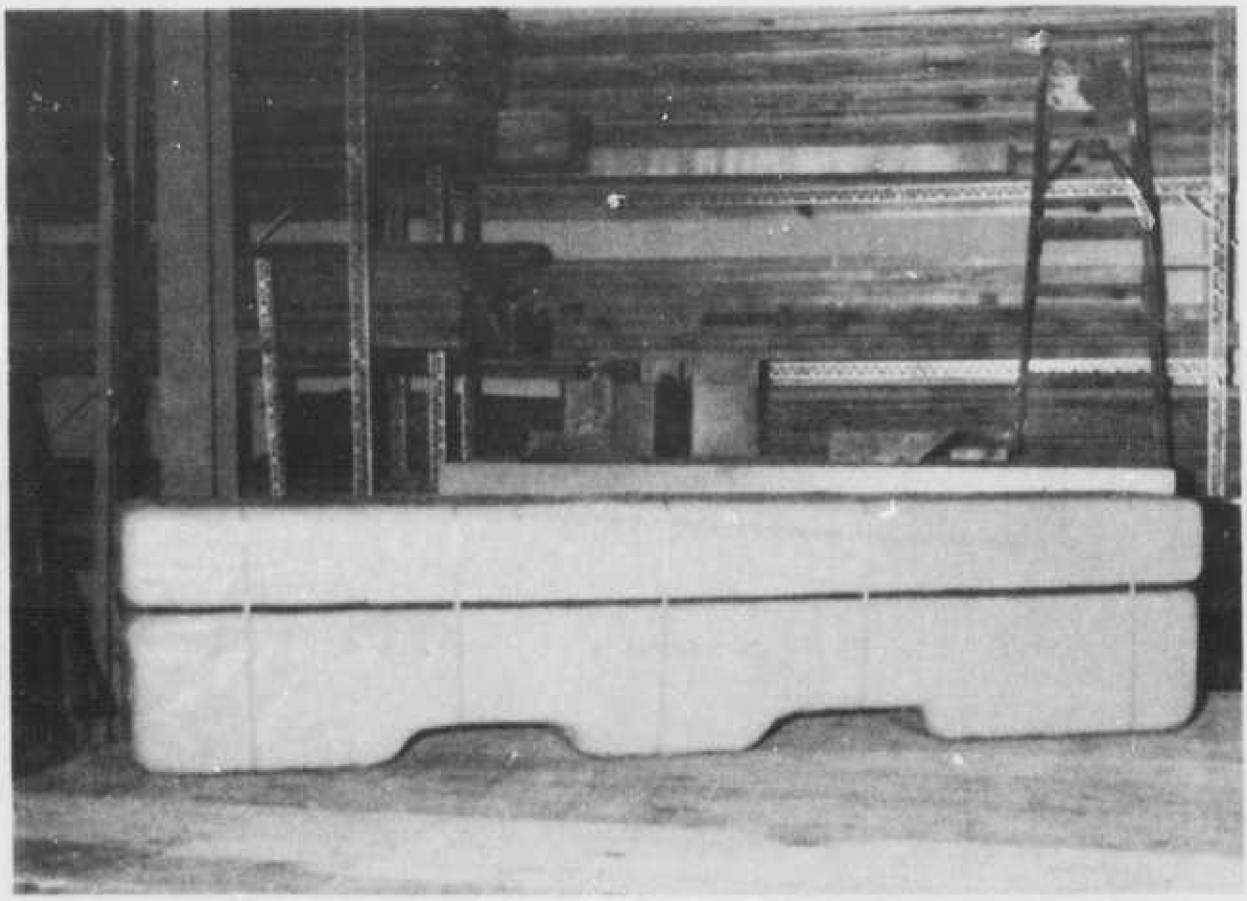

Figure 6. CNU-100 Container in Closed Condition

TABLE IV

CONTAINER TESTING (NON-INSTRUMENTED)
36" DROP HEIGHT
CORNERS REINFORCED WITH 2 LAYERS FIBERGLASS CLOTH/POLYESTER

CONTAINER NO.	TYPE OF CONT	EPOXY FOAM DNSTY PCF	F/P* SKIN WT LBS	EMPTY CONT WT LBS	WT OF ITEM	CONTAINER IMPACT LOCATION EDGE-WISE (1-2)	EDGE-WISE (3-4)	CORNER 1	CORNER 2	CORNER 3	CORNER 4	COMMENTS
ROOM TEMPERATURE TESTING												
169136	AIM-7 LARGE	4.2	35.7	116.2	150	Pass	Pass	Pass	Crushed	Crushed	Crushed	Fig 8 shows typical Crushing of Corners
169147	AIM-7 LARGE	4.2	45.4	116.9	150	Pass	Pass	Pass	Pass	Pass	Pass	Slight Fracture Lines. No Skin Separation.
169154	AIM-7 LARGE	3.4	50.4	107.6	150	Pass	Pass	Pass	Pass	Pass	Pass	Fracture Marks Only - No Separation.
169151	CNU-100	6.6	59.3	136.9	260	Pass	Pass	Pass	Pass	Pass	Pass	Fracture Marks Only - No Separation.
COLD TEMPERATURE TESTING (-40°F)												
169154	AIM-7 LARGE	3.4	50.4	107.6	150	Pass	Pass	Pass	Pass	Pass	Pass	Some Abrasion Marks

*FIBERGLASS/POLYESTER

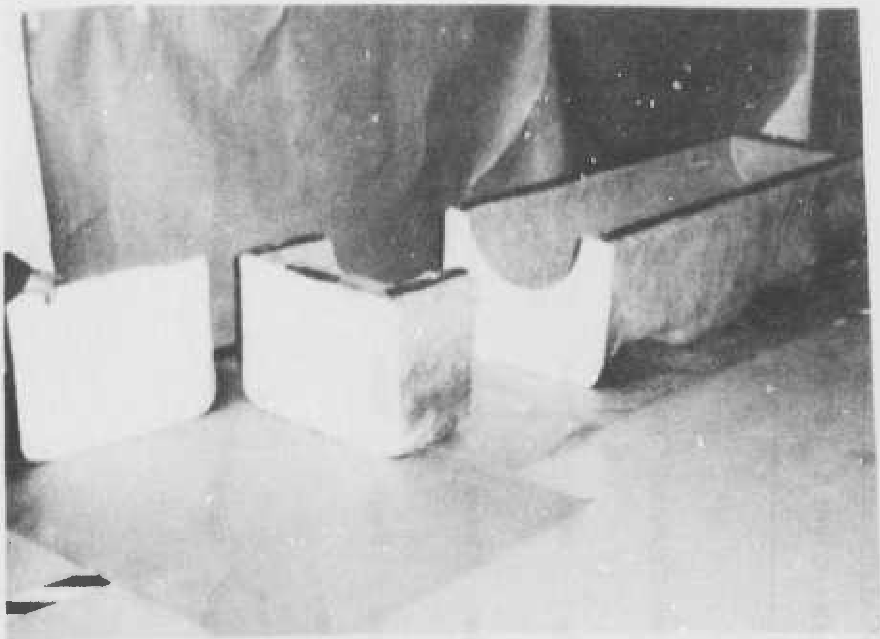

Figure 7. Cross-Section of Container Showing the Foam and Fiberglass/Polyester Skins

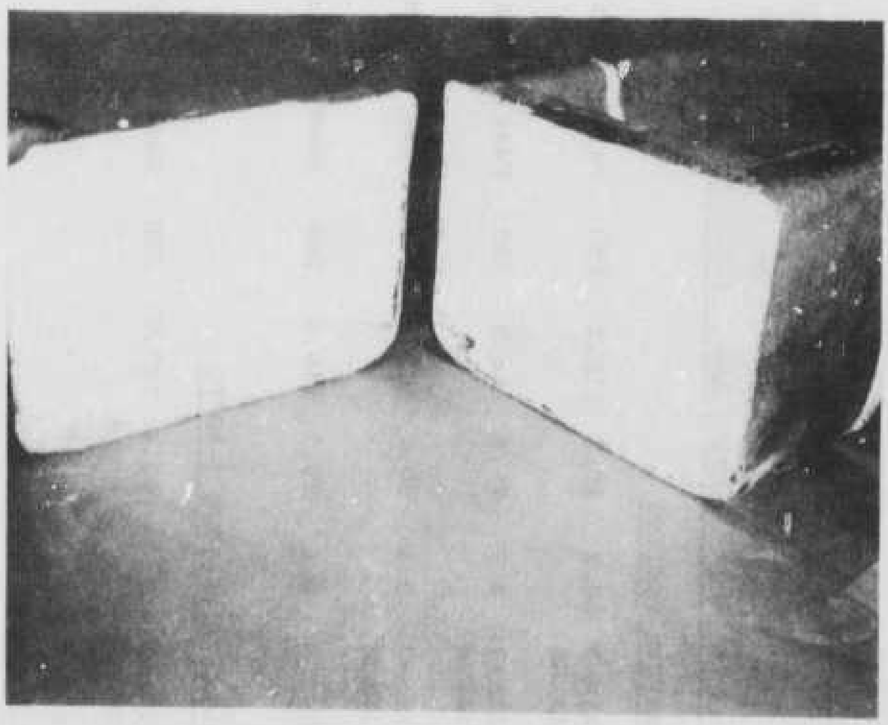

Figure 8. Close-up of the Above Showing the Crushed Corners of the Container

COST EFFECTIVENESS

A very significant objective of the program was to provide cost effectiveness in the manufacture of small as well as large quantities of containers. For a small number of containers the cost effectiveness of the manufacturing system is dependent on inexpensive molds such as plywood. The manufacturing of a large number of containers is dependent more on the minimizing of labor by mechanization. The higher cost of the required metal molds can be amortized over a large quantity of containers.

The Monsanto epoxy foam manufacturing system requires only plywood molds for low volume production of containers. For larger quantities fiberglass, or sheet metal is adequate. The rotomolded polyethylene container filled with 2 pcf polyurethane foam requires considerably more expensive steel molds.

Table V shows the estimated costs of containers produced by four types of manufacturing systems. Establishing the relative cost effectiveness of the manufacturing systems was complicated by the fact that the recommended Monsanto system is new and no precedents have been established for production quantities.

Table VI gives the estimated costs of equipment for the four container manufacturing systems. The polyurethane foam and steel container manufacturing systems were included for comparative purposes. The polyurethane foam process is very similar to the epoxy foam system.

The Monsanto epoxy and the polyurethane foam systems offer savings in other areas that are difficult to evaluate, such as lessening of skilled labor requirements, and reduction in the inventory of packaging materials by the use of one set (two components) of chemical liquids instead of the multiplicity of materials now used in packaging of items. Other aspects that present a potential for cost savings are the reduction of shipping costs resulting from the weight reduction of containers, improved standardization of container design, and the capability of manufacturing containers on site.

With advancements in the technology of polyurethane foam and coatings and the many formulations that are becoming available, the potential for developing a more practical and cost effective manufacturing system is becoming a greater possibility. Related investigations in polyurethane technology show that polyurethane foam is competitive in cost, has improved physical properties over epoxy foam, the same low mold cost and is adaptable to a simplified manufac-

TABLE V

COST EFFECTIVENESS
(Estimated)

CONTAINER SYSTEM	COST (EACH) QUANTITY OF: 47,000	COST (EACH) 1000	COST (EACH) 100	COST (EACH) 10
CNU-100 - Rotomolded Polyethylene, cavities filled with 2 pcf polyurethane	$60*	$90	$120	$200
CNU-100 - Monsanto Epoxy Foam - Fiberglass Coated	$65	$70	$ 75	$ 80
CNU-100 - Polyurethane Foam**	$60	$65	$ 70	$ 75
CNU-100 - Steel Container**	$105	$125	$150	$190

*Production Cost (Actual).
**The Polyurethane Foam and Steel Container were added for comparative purposes only.

TABLE VI

EQUIPMENT
FOR
MANUFACTURING CNU-100 CONTAINERS
ESTIMATED

Rotomolded Polyethylene	Rotomolding Equipment		$55,000
	Oven		20,000
	Misc		5,000
		TOTAL	$80,000
Monsanto Epoxy Foam Manufacturing System	Oakes Dispensing Equipment		$10,000
	Tanks, Valves, Misc.		5,000
		TOTAL	$15,000
Polyurethane Foam Manufacturing System	Foaming Equipment		$ 4,000
	Misc		1,000
		TOTAL	$ 5,000
Steel Container Manufacturing System	Fixtures, Metal Forming and Welding Equipment		$80,000

turing system. The polyurethane foam dispensing equipment required is approximately the same in cost as the Oakes equipment used with the epoxy foam. All ALCs now have the polyurethane foam dispensing equipment available.

CONCLUSIONS

The major objective of this development program: to determine the feasibility of a new cost effective plastic material and manufacturing system for the fabrication of both small and large numbers of shipping and packaging containers for military items has been attained. Specifically, the following was achieved:

a. A plastic material formulation of froth foam epoxy coated with polyester/fiberglass has been identified which can be manufactured in a cost effective manner into shipping and packaging containers.

b. A manufacturing process system was demonstrated for the fabrication of prototype containers. The system is simple, efficient, and requires relatively low cost tooling and equipment.

c. Containers (AIM-7 and CNU-100), that were fabricated with the recommended materials and manufacturing system, have met the test and evaluation requirements of Federal Test Method Std No. 101B, Method 5005 (Cornerwise Drop Test), Method 5008 (Edgewise Drop Test) and Method 5012 (Pendulum Impact Test).

d. The AIM-7 epoxy container cushioned with 1-1/2 pcf flexible polyurethane foam, MIL-P-26514, limited shock inputs to a level of 24 G's or less. The maximum specified rating for the item is 30 G's. These results indicate that items such as the AIM-7 can be cushioned and packaged successfully in this type of plastic foamed container system.

RECOMMENDATIONS

a. It is recommended that the program of developing a simplified method of manufacturing specialized containers for missiles, and other high density items for production quantities be continued under separate project investigations. Further refinement and simplification of equipment and processes should be pursued.

b. It is recommended that polyurethane foam systems be further investigated as another container manufacturing system.

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Container	Polyurethane Foam	AIMS-7 Missile
Plastics	Polyethylene Foam	CNU-100 Bomb Dispenser
Foams	Polyester/Fiberglass	Packaging Container System
Foam Froth	Test & Evaluation	Manufacturing
Epoxy Foam	Cushioning	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Prototype containers~~, developed and furnished by Monsanto Research Corporation under Contract F33601-72-C-0424,~~ were evaluated according to Federal Test Method 101B, Method 5005 (Cornerwise Drop Test), Method 5008 (Edgewise Drop Test) and Method 5012 (Pendulum Impact Test). The containers met these requirements. The AIM-7 containers cushioned with MIL-P-26514 polyurethane foam provided shock attenuation of not more than 24 G's. (The maximum allowable was 30 G's.) The Monsanto manufacturing method, while cheaper and simple than conventional container manufacturing methods, still requires specialized

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equipment. Further development is recommended into other promising methods and materials such as the polyurethane foam methods and technology.